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Author(s)	Suharyanto, Matsushita, Jun
Citation	Society for Social Management Systems Internet Journal, 5(1)
Date of issue	2009-03
URL	http://hdl.handle.net/10173/1751
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Text version	publisher

Comparative Study of Basin-Based Wastewater Management for Industrial Pollution Control in Upper Citarum River Basin, West Java, Indonesia

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A B S T R A C T

Industrial sector in the Upper Citarum River Basin (UCRB), as one of the major basins in Indonesia, has own very rapidly to support national economic growth. Various industries grow in the basin such as textile, food and metal manufacturing industries. Land conversion for industries has increased about 35% in 2002 compared with that in 1993 (Wangsaatmaja, 2004). Consequently, this development has given a huge impact on quality of water bodies due to the discharge of industrial pollutant. A basin-based wastewater management (BBWM) approach has been conducted in the previous paper (Suharyanto & Matsushita, 2008). Herein, a similar study is conducted in this paper with respect to the industrial wastewater. The aim of this study is to investigate a BBWM approach dealing with for industrial pollution control in the UCRB. A comparative analysis of BBWM in three different countries: Japan, The Netherlands, and Indonesia is incorporated in the study. Both Japanese & Dutch systems are well-developed in terms of structural and non-structural measures in dealing with pollution from industrial sector. On the other hand, current industrial pollution in the UCRB shows a high threat on surface water quality due to uncontrolled wastewater discharge from various industries. A large proportion of pollutant load from industries has been indicated. The study suggests that the UCRB should consider achieving a well-combination of structural and non-structural measures. High coverage of structural and non-structural measures through an increase in a number of wastewater treatment plants (WWTPs) together with an increase in treatment performance bring about a better effect on pollutant reduction as indicated from Japan and The Netherlands' cases. Efforts should be undertaken to dwindle the gap in the shortage of proper structural and non-structural measures. Additionally, design of future comprehensive BBWM needs to be formulated for better management of industrial wastewater in the UCRB by analyzing all aspects related to structural and non-structural measures in the total basin perspective. The cluster system analysis would be highly indispensable for further study in which analysis of industrial zones is incorporated.

Keywords: Basin-based wastewater management, industries, Pollutant load, Upper Citarum River Basin,

1. INTRODUCTION

1.1 Basin-Based Wastewater Management (BBWM) Approach

A basin-based wastewater management (BBWM) perspective is a comprehensive approach that could probably be required to deal with the water quality management in the UCR Basin. Previous study on BBWM approach has been introduced (Suharyanto & Matsushita, 2008) which views the perspective from a basin-wide context through the assessment of structural measure (e.g. public sewage work) and non-structural measure (e.g. private-initiated individual sewage treatment) in dealing with domestic wastewater. Herein, a similar study is conducted and presented in this paper with respect to the industrial wastewater. The aim of this study is to investigate a BBWM approach with the perspective of a basin-wide context through the assessment of both measures dealing with for industrial pollution control in the UCRB.

Integrated management approach in linking related variables in the basin, which contribute to give impact on surface water quality is required in building a comprehensive solution dealing with water pollution prevention and control. In addition, an integrated approach through BBWM should be introduced to cope with decreasing surface water quality. BBWM approach on water pollution control would be needed especially under: (1) rapid urbanization, (2) weak governance, (3) low financial support, (4) limited and slow development of public sewerage system (Matsushita, 2007). Under such a situation, BBWM plays an important role in the total view of wastewater management in the basin by overcoming any shortage of measures.

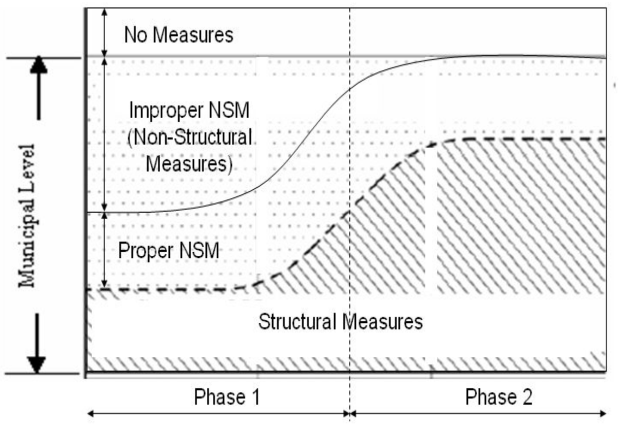


Fig.1 Basin-based management approach (Adjusted from Matsushita, 2007)

The frame of BBWM puts a basis of water-related infrastructure management including wastewater in the river basin especially in the cities with very rapid urbanization focusing on two essential mitigating measures: (1) Structural Measures, (2) Non-Structural Measures (Matsushita, 2007). In the wastewater concern, structural measures mainly focus on public infrastructure making such as public sewerage construction; Non-structural measures focuses on private-initiative infrastructure building such as private-initiative on-site wastewater treatment system. The role of structural and non-structural measures in the frame of basin-based wastewater management has been so essential that the basin with very high population growth suffering from heavy pollution could be overcome through applying these two measures composing an integrated approach. The evaluation of basin-based wastewater management in Japan indicates that during high economic growth (1960s) the role of non-structural measures were applied as supplementary measures based on private initiative due to weak governance during an early stage of that period.

Table 1 Step-by-Step Water-related Infrastructure Building Process in Japan (1940s-2000s) concerning Pollution Control (Matsushita, 2007)

Phase	**Socio-economic Conditions**	**Water-related Infrastructure Building**
Phase 1 (1940s-50s)	Economic Rebuilding	National-basis river works and *pollution control*
Phase 2 (1960s)	High Economic Growth	On-site type facilities by private initiatives
Phase 3 (1970s-1980s)	Aftercare for Oil Crisis	Promotion of water-resources saving schemes (e.g. wastewater reuse) leading to less water pollution
Phase 4 (1990s-2000s)	Creation of Sustainable Society Models	Stimulating of public participation

2. BACKGROUND AND OBJECTIVE

2.1 Background

Citarum Basin is a highland and surrounded by mountains located in West Java Province, Indonesia. The area of upper Citarum Basin is 2,340 km2. with the population of 5.7 million (2001) and the average density of about 25 People/ha. Citarum River is one of strategic rivers in Indonesia from which main supply for 3 multipurpose dams (drinking, agriculture, fisheries, irrigation, and hydropower generator for Java and Bali Islands) originates.

Industrial sector in the UCRB, as one of the major basins in Indonesia, has grown very rapidly to support national economic growth. Various industries grow in the basin such as textile, food and metal manufacturing industries. Land conversion for industries has increased about 35% in 2002 compared with that in 1993 (Wangsaatmaja, 2004). Consequently, this development has given a huge impact on quality of water bodies due to the discharge of industrial pollutant.

2.2 Impact of industrialization on water quality

The empirical evidence has confirmed the close relationship between urbanization and also industrialization with water quality. Pressing on water environment increases as industrialization grows very rapidly. The development of industrial sector in the UCRB indicated by several zones has also given a huge impact on quality of water bodies

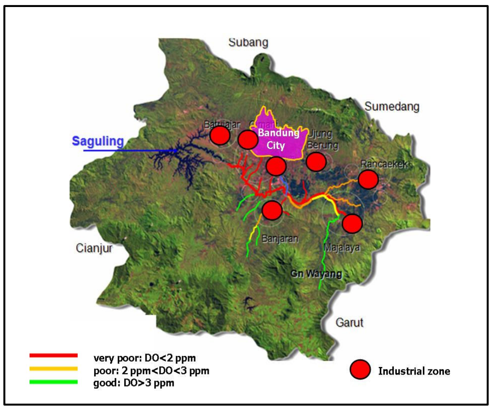


Fig.2 Industrial zones in the UCRB that contribute to the decrease of DO (Wangsaatmaja, 2004)

due to the discharge of large pollutant load. As the description of impact which has been received by water bodies in the UCRB, Fig. (Wangsaatmaja, 2004) shows dissolved oxygen (DO) content has depleted and become extremely low (red color) particularly in the segment where the activities of urban and industries are very intensive in that region.

2.3 Objective

As a response to the aforementioned issues, this study aims to evaluate BBWM in the UCRB related to water pollution due to the industrial wastewater. The analysis is based on the comparison of several aspects related to structural and non structural measures as well as the implication on the pollutant load and discharge in each system. BBWM system of three different regions: Upper Citarum Basin, West Java (Indonesia), Suwa Basin, Nagano (Japan), and Delfland, South Holland (The Netherlands) is incorporated in this study.

Table 2 Industrial cluster in the UCRB, West Java, Indonesia

Area	Industrial cluster	Number of industries	Type of industry
Bandung city	Majalaya	56	Textile*),
	Dayeuhkolot	45	Textile*), Electroplating, Pharmacy
	Batujajar	20	Textile*),, Electroplating, Chemical, Printing, Painting
	Banjaran	8	Textile*), Chemical
	Rancaekek	9	Textile*), Electroplating
Bandung regency	Ujung Berung	23	Textile*)
Cimahi city	Cimahi	56	Textile*)

*) Dominant industry

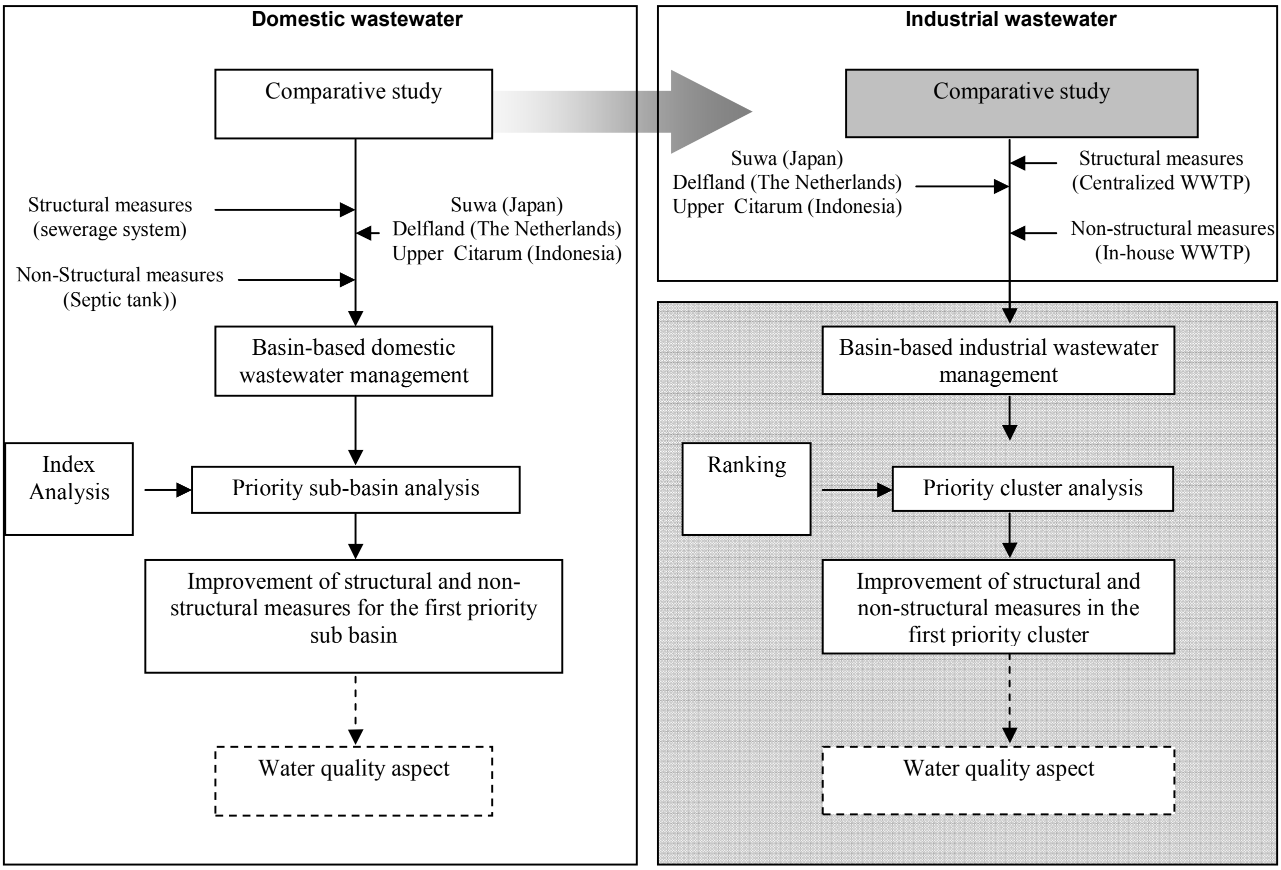


Fig.3 Study Approach

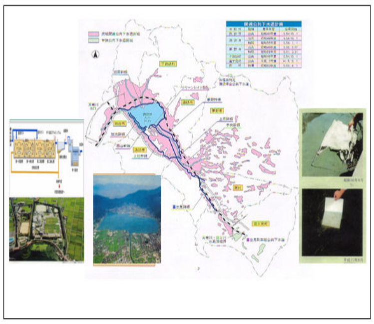
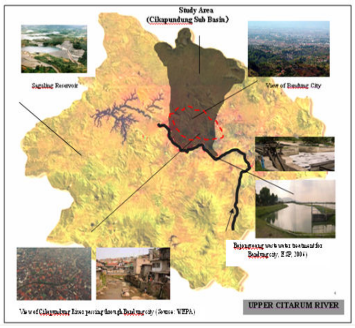
 Fig. Suwa Basin, Japan (Nagano Pref., 2007)	 Fig. Delfland Area (www.hhdelfland, Enserink, 2003)	 Fig. Upper Citarum River Basin, Indonesia
Area: ±515 km2 Location: Nagano Prefecture, Japan Number of industries: ± 1521; Gross product of ¥631,900 million/year (www.ilec.or.jp); Population: about 1,400,000 (2000).	Area: ±410 km2 Location: South Holland, The Netherlands Gross Regional Product per capita of about US$36,940 (Source: World Bank Institute) Population: about 1,250,000 (2003);	Area: +2.340 km2 Location: West Java Province, Indonesia Number of industries: > 360 Population: about 5,700,000 (2001).

Fig.4 Comparison of the three study areas

3. METHOD

This study investigates BBWM related to industrial water pollution. A similar study investigating the same issue has been conducted with respect to domestic wastewater. The previous study indicated that BBWM was successfully applied in Japan to reduce pollutant load through structural and non-structural measures (Suharyanto & Matsushita, 2008). The principle of integrating environmental protection & economic development should be performed appropriately instead of ‘grow now clean-up later’ approach (Matsushita, 2007). Herein, in this paper BBWM approach is introduced with the perspective of a basin-wide context through the assessment of structural and non-structural measures dealing with industrial wastewater management. Three different basins were incorporated in the comparative study. Each basin is analyzed particularly from the viewpoint of public sewerage system (structural measure) and on-site wastewater treatment system (non-structural measure). Comparing structural and non-structural measures could recognize and assess the degree of BBWM implementation in each basin. Furthermore, this leads to assess the impact of each system’s performance on pollutant discharge and further on water quality.

4. COMPARISON OF BBWM OF THE THREE COUNTRIES

4.1 Current system on BBWM in Suwa, Japan

(i) Policy and regulation

Concern over environmental problem especially since the huge public health issue marked with bitter case of Minamata disease has increased rapidly in Japan. New regulations were established to deal with pollution problem and protect the environment. Policy and regulation that have been established associated with water pollution control in Japan includes: (a) Water Pollution Control Law (WPCL) which was introduced in 1970 and revised in 1978 with measures to reduce phosphorous pollution and a system of area-wide total pollutant load control introduced, (b) WPCL was amended (1983) and the area-wide pollution control system for organic matter was introduced for Tokyo Bay, Ise Bay, and Seto Inland Sea, (c) Special law for water quality control in lakes (1984). The regulation concerning with protecting the environment which was established has stimulated the development of structural and non-structural measures in Japan.

(ii) Structural and non-structural measures

The decrease in pollutant load in the study area of Suwa Basin has been resulted from the implementation of both structural and non-structural measures. Structural measure is applied through public sewage system, while non-structural measure includes in-house wastewater treatment plant (WWTP). In the case of wastewater discharged from industries, it is allowed to be drained into the public sewerage provided that certain standards are fulfilled. As such criteria and target cannot be achieved, the wastewater discharge is prohibited to enter the public sewerage. Instead, they have to build their own facilities for controlling the pollution. Additionally, direct discharge (dotted line in the figure) is only possible as the water quality standard can be fulfilled under Water Pollution Control Law. However, this portion has been reduced as structural measures become well-established (marked with the construction of Clean Lake Suwa WWTP, which has operated since 1979)

In terms of structural and non-structural measures that have been established, the Japanese system has been well-developed. High coverage of structural and non-structural measures through an increase in a number of treatment plants (WWTPs) together with an increase in treatment performance bring about a better effect on pollutant reduction. The construction of Clean Lake Suwa (Toyoda sewage treatment plant) has resulted in a major improvement in the Suwa area. Besides, non-structural measure in the form of in-house treatment was established as a means to control the pollution. As the structural measure subsequently develops at the later stage, wastewater from industries could be discharged into public sewerage provided that pre-treatment was conducted and certain required standard is satisfied.

(iii) Reduction of pollutant load by measures

The following figure indicates the effect of reduced pollutant load by the combination of structural and non-structural measures in the Japanese system. A high removal of pollutant load in terms of COD can be seen below. This highly improved condition of reduced pollutant load could reflect the effective measures of BBWM system in Japan in which the structural measures play a more important role at the next stage as they have become well-developed. In the previous stage where when the structural measures have not yet been well-developed, non-structural measures hold the significant role in controlling pollution.

4.2 Current system on BBWM in Delfland, The Netherlands

In The Netherlands, including Delfland, industrialized zones largely corresponds with highly populated zones

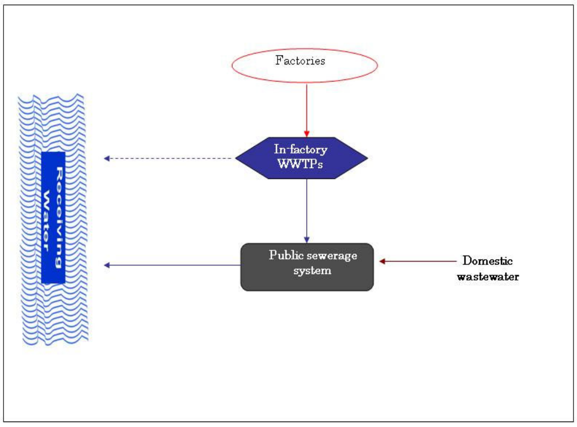
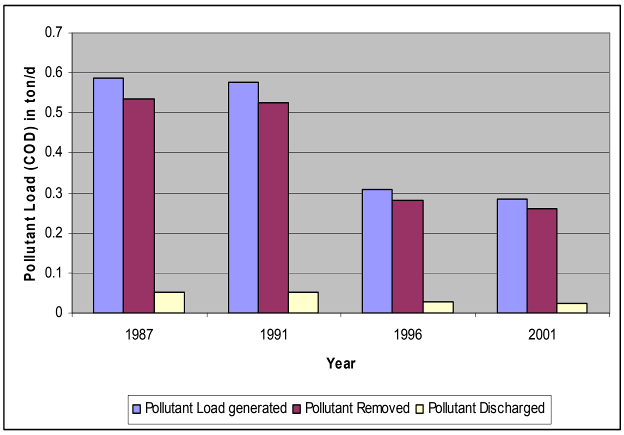


Fig.5 Scheme of structural and non-structural measures in Japanese system

(Vethaak et al., 2005). In economic terms, a significant fraction of the most important industries and activities are located in South Holland (Vlies et al.).



Note: Estimated using 91% removal efficiency of COD by Clean Lake Suwa (Toyoda WWTP) which has operated since 1979

Fig.6 Decrease in pollution load in Suwa Basin, Japan (Nagano Pref., 2007)

(i) Policy and regulation

Although water pollution became worse at the end of the 19th century in The Netherlands, it was only in 1970 that the Dutch pollution of Surface Water Act became into existence (Claassen, 2007). Before 1970, hardly any treatment of wastewater took place and surface waters became very polluted, especially in the cities. The largest bottlenecks in point sources of water pollution have been tackled beginning around 1990, after a period of 20 years of sanitation. The sewerage systems of cities and larger villages became connected to new-build WWTPs (Claassen, 2007). The issue of Dutch "Law Pollution Surface Water" (LPSW) became an important step for an increase in the construction of

WWTP in The Netherlands and this also marked the start of municipal and provincial government to transfer the management of WWTP to the water board. Some guiding principles as regards water pollution control generally in The Netherlands include: (a) The LPSW is mainly concerned with point sources, (b) The role of Water Boards (WBs) as the authority related to a permission for discharging wastewater; It is not allowed to discharge used water into surface water unless permission is obtained, (c) The implementation of guiding principle of the polluter pay principle

(ii) Structural and non-structural measures

The WBs have played a major role both in water quantity and water quality management in the Netherlands. The role of WBs in water quality has started since the Water Pollution Act was introduced.

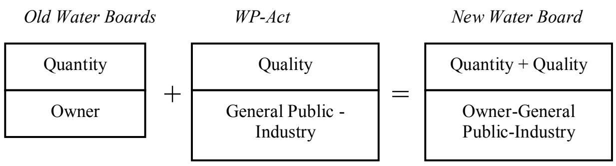


Fig.7 Water Boards before and after the Water Pollution Act (Schut, 1995)

The water board has the responsibility to build the new treatment plants and also modify the existing ones in order to comply with the standard stipulated by the law. The expense obtained for these purposes comes from the payment of the polluters including the industries.

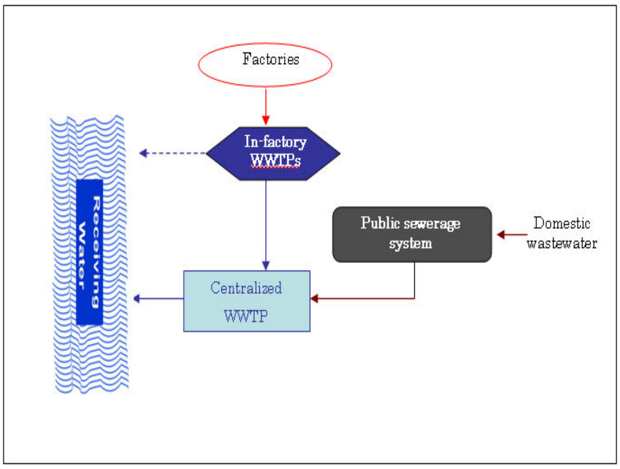


Fig.8 Scheme of structural and non-structural measures in Dutch system

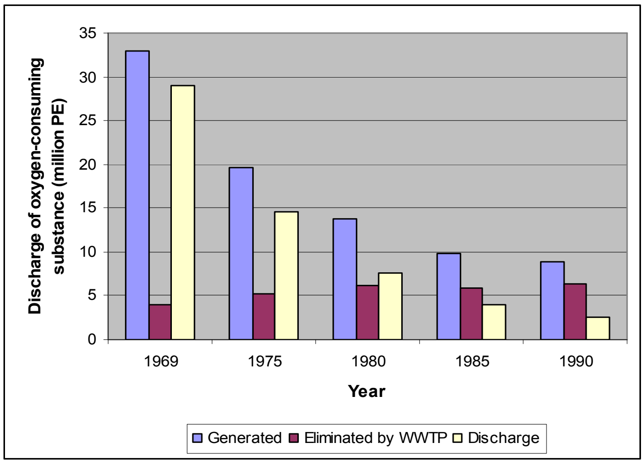
The higher the pollutant load, the higher they have to pay. In the case of Delfland,WB which had managed the Houtrust wastewater treatment plant (WWTP) and Harnaschpolder, currently has involved private sector to manage the WWTPs which treat wastewater from industry and inhabitants. In 2008, Harnaschpolder, which is the largest WWTP in The Netherlands, and Houtrust WWTP purify the water of 1.5 million people and 40,000 companies (Veolia, 2008)

(iii) Reduction of pollutant load by measures

The decreasing trend of pollutant discharge in the Netherlands system can be seen in Table showing the impact of Water Pollution Act on industrial wastewater discharge, while the Fig.9 below indicates that the industrial wastewater generation decreases, while at the same time the amount eliminated by wastewater treatment plant increases.

Table 3 Discharge of oxygen consuming substances per million population equivalent (Adjusted from Schut, 1995)

	1969	1975	1980	1985	1990
Industrial	33.0	19.7	13.7	9.8	8.8
Eliminated by WWTP	3.98	5.19	6.16	5.84	6.31
Discharged	29.01	14.50	7.53	3.95	2.48



Note: The estimation of pollutant load reduction indicated in the figure is based on the overall trend

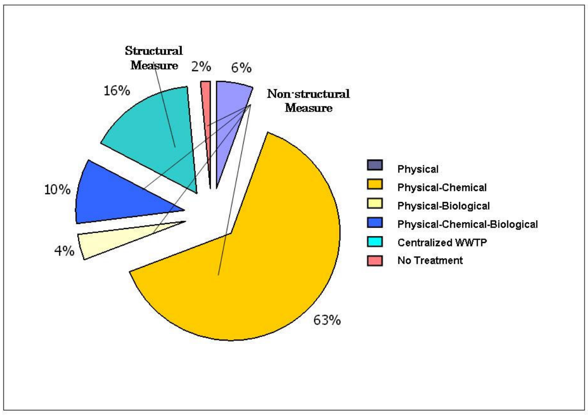
Fig.9 Discharge of oxygen consuming substances per million population equivalent (Adjusted from Schut, 1995)

4.3 Current system on BBWM in UCRB, Indonesia

Expansion of manufacturing industry has depended on and in its turn stimulated urbanization. The UCRB (Bandung basin) is long-time producer of textiles and agro-products and was swept along in the extremely rapid industrial expansion of the 1970s and 1980s (Braadbaart, 1997). Textile industry is the dominant industry in the UCRB with the percentage of almost 80%.

(i) Policy and regulation

Policy and regulation that have been established associated with environmental management and water pollution control for the UCRB includes: (a) Law No. 23/ 1997 about Environmental Management, (b) Government Regulation: PP No 20/1990 and 82/2001 (Revision) about Water Pollution Control, (c) Ministry of Environment (KepMenLH) 51/1995: Effluent standard for various industries, (d) PROKASIH (Clean Water Program), SUPERKASIH, PROPER Programs.



Note: Based on the available data from Environmental Division, Bandung Regency, 2004

Fig.11 Structural and non-structural measures by treatment method in the UCRB

(ii) Structural and non-structural measures

A general picture of structural and non-structural measures as regards industrial wastewater treatment in the UCRB could be seen in the Figure. It indicates that non-structural measure through individual on site system is the majority in the basin with the treatments include physical, physical-chemical, physical-biological, physical-chemical-biological. On

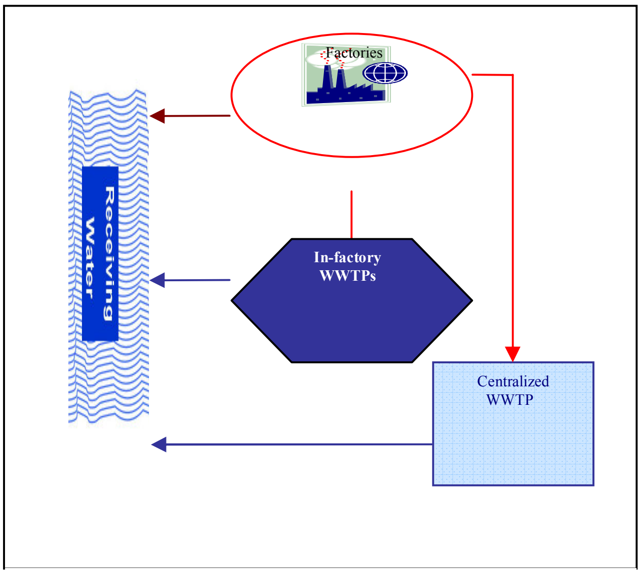


Fig.10 Scheme of structural and non-structural measures in Indonesian system

the other hand, the structural measure is indicated by the centralized wastewater treatment plant covers 16% as can be seen in the Fig. Apart from the sufficiency and efficiency of the treatment, most of industries in the UCRB have provided their operation with wastewater treatment plant (WWTP) in which different types of treatment are applied: physical, physical-chemical, physical-chemical-biological treatment.

Additionally, a centralized wastewater treatment plant (Cisirung WWTP) has been initiated to treat wastewater from various industries in the Dayeuhkolot area in which most of industries are textile. Cisirung WWTP has been constructed to reduce the pollutant load generated from industries in the Dayeuhkolot region. Cisirung Centralized Industrial wastewater treatment plant was established with an objective to control the pollution from the industrial zones nearby with the centralized plant. Sewerage work for centralized WWTP was constructed to provide treatment for the nearest industries with the majority of textile industries (the remaining industries include chemical, food and electronic). Currently Cisirung WWTP treats more than 30 industries with the majority of textile industry covering about 7.56 tonnes BOD/d.

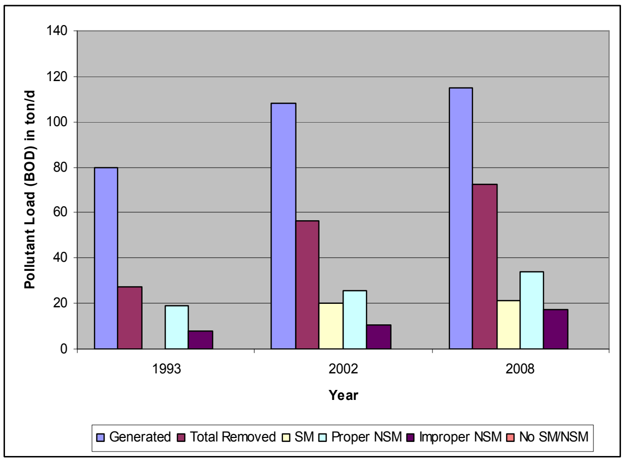


Fig.12 Pollutant Load (BOD) in Indonesian system

In terms of pollution charging system in the UCRB, ‘Polluter Pay Principle’ (PPP) applied to BOD load is a familiar management concept. However, it has not been applied in the UCRB and its introduction will require dialogue with the (influential) industry sectors that could be expected to challenge it. Arbitrarily setting the charge will be resisted (EARF, 2006).

(iii) Reduction of pollutant load by measures

As can be seen from Fig.12, The pollutant load in the UCRB still tends to increase above 100 ton/d in terms of BOD. On the other hand, a relatively large portion of total pollutant load still remains and this is potentially discharged into the receiving water bodies. However, an approach of installing a centralized Cisirung WWTP in around 2001 could significantly reduce the pollutant load as it is operated and maintained properly. In order to achieve the objective to reduce the pollutant load, concern over various aspects on improvement program towards an ideal operation and maintenance of this centralized WWTP should be taken into account, which would include an increase in awareness of industries and all other related stakeholders in the operation and maintenance of the treatment facilities.

5. CONCLUSION

Well-developed system in terms of structural and non-structural measures indicated by high coverage of structural and non-structural measures through an increase in a number of treatment plants (WWTPs) together with an increase in treatment performance bring about a better effect on pollutant reduction are reflected in Japan and The Netherlands' cases.

In Japanese system, non-structural measure in terms of in-factory treatment was established as a means to control the pollution. As the structural measure subsequently develops, wastewater from industries could be discharged into public sewerage provided that pre-treatment was conducted and certain required standard is satisfied. After increasing, well-established structural measure was developed, it plays an important role in wastewater management after in the initial phase non-structural measure was the dominant measure.

Dutch system shows that a dramatic increase in a number of industrial WWTPs after initiating Water Pollution Control Act, introducing a levy system and Water Board as one of supervision bodies, has strongly reduced the pollutant load from industries. Polluter Pay Principle has been well-implemented both in Japan and The Netherlands resulting in very significant reduction in pollutant load. However, this pollution charging system in the UCRB although such as applying to BOD load is a familiar management concept, has not been applied in the UCRB due to a lot of resistance. A certain approach is required supported by various aspects and mechanisms to successfully implement it in the UCRB.

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